

Laboratory Evaluation Tera Sensor NextPM



Outline

1. Background
2. PM_{2.5}
3. PM₁₀

DRAFT

Background

Three Tera Sensor NextPM (hereinafter NextPM) sensors were field-tested at the South Coast AQMD Rubidoux fixed ambient monitoring station (09/29/2021 to 11/28/2021) under ambient environmental conditions. Following field-testing, the same two units (Units 1222 and 1342; Unit 1207 was not functioning properly and was not included in the laboratory evaluation) were evaluated in the South Coast AQMD Sensor Environmental Testing Chamber 2 (SENTEC-2) under controlled artificial aerosol concentration/size range, temperature, and relative humidity.

NextPM (2 units tested in the lab):

- Particle sensor: **optical; non-FEM (Tera Sensor - NextPM)**
- Each unit reports: PM_{1.0}, PM_{2.5} and PM₁₀ (µg/m³)
- **Unit cost: ~\$70**
- Time resolution: 10 seconds
- Units IDs: 1222, 1342



Reference instruments:

- PM_{2.5} instrument (**Teledyne T640x, San Diego, CA; hereinafter FEM T640x**); **cost: ~\$37,000**
 - Time resolution: 1-min
- PM₁₀ instrument (**non-FEM, APS, TSI, Shoreview, MN**); **cost: ~\$55,000**
 - Time resolution: 1-min



FEM T640x



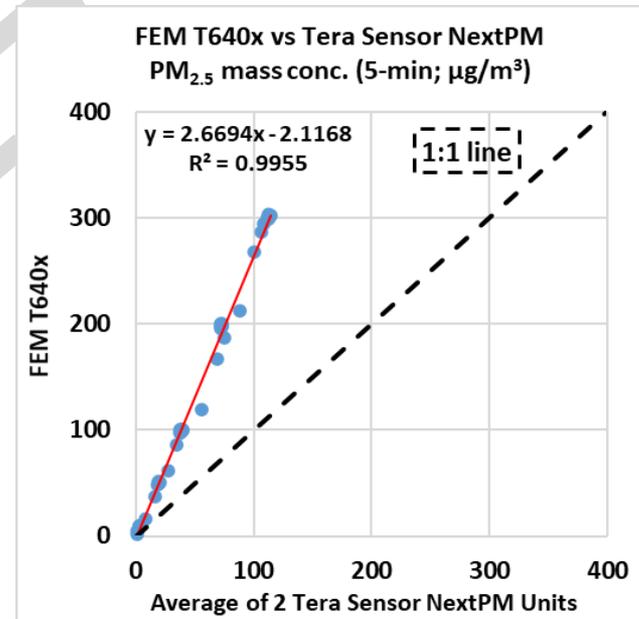
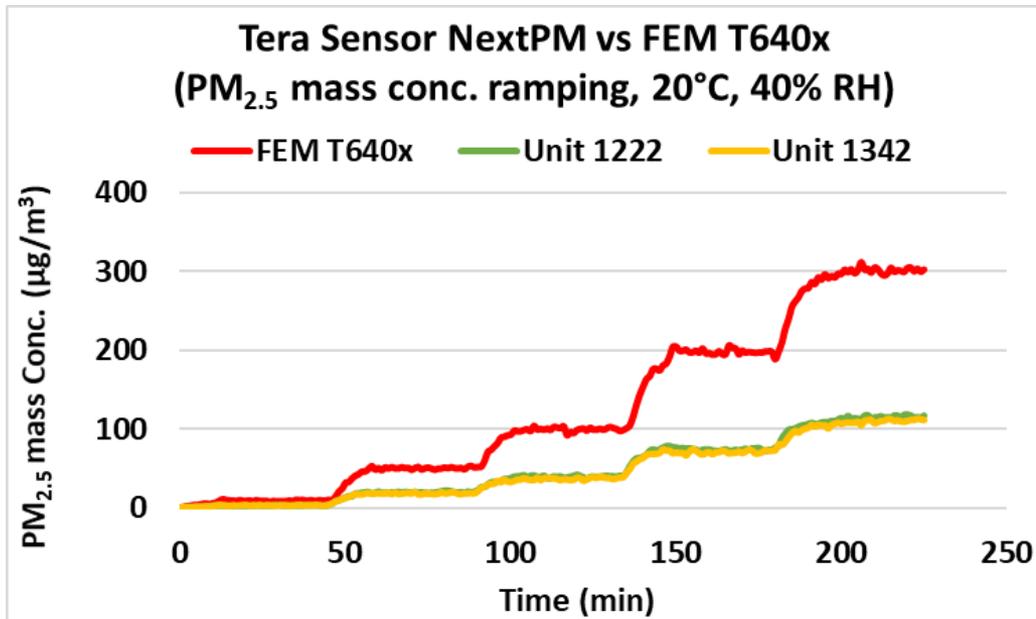
APS

PM_{2.5}

1. **FEM T640x vs NextPM**
2. **Accuracy, data recovery, and intra-model variability**
3. **Precision**
4. **Climate susceptibility**
5. **Discussion**

NextPM vs FEM T640x (PM_{2.5})

Coefficient of Determination



- The NextPM sensors tracked well with the concentration variation but underestimated PM_{2.5}, compared to the FEM T640x in the concentration range of 0 - 300 µg/m³.

- The NextPM sensors showed very strong correlations with the FEM T640x PM_{2.5} mass conc. ($R^2 > 0.99$)

NextPM vs FEM T640x PM_{2.5} Accuracy

- Accuracy (20 °C and 40% RH)

| Steady State # | Sensor Mean (µg/m ³) | FEM T640x (µg/m ³) | Accuracy (%) |
|----------------|----------------------------------|--------------------------------|--------------|
| 1 | 3.1 | 9.1 | 34.2 |
| 2 | 19.3 | 50.4 | 38.2 |
| 3 | 39.0 | 99.3 | 39.2 |
| 4 | 72.7 | 197.5 | 36.8 |
| 5 | 113.5 | 301.6 | 37.6 |

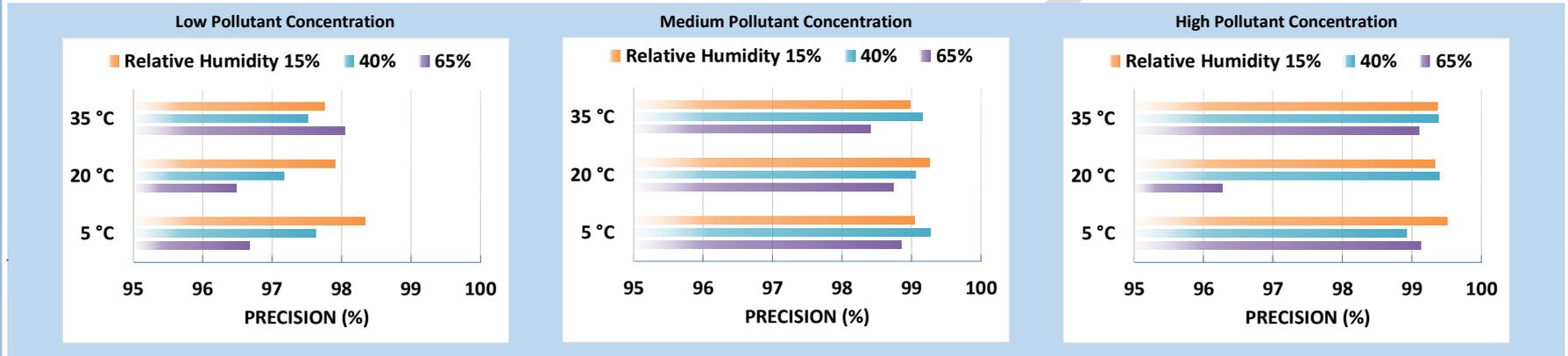
- The NextPM sensors underestimated PM_{2.5} concentration values compared to the FEM T640x PM_{2.5} mass concentration at 20 °C and 40% RH. The NextPM sensors showed fairly constant accuracy (34.2% to 39.2%) for all tested PM_{2.5} concentrations compared to the reference FEM T640x for the entirety of test.

NextPM Data Recovery and Intra-model Variability

- Data recovery for PM_{2.5} measurements was 100% for Units 1222 and 1342
- Low PM_{2.5} concentration variations were observed between the two units at 20 °C and 40% RH, at 10, 50, and 150 µg/m³ PM_{2.5} as measured by the FEM T640x.

Precision: NextPM (PM_{2.5})

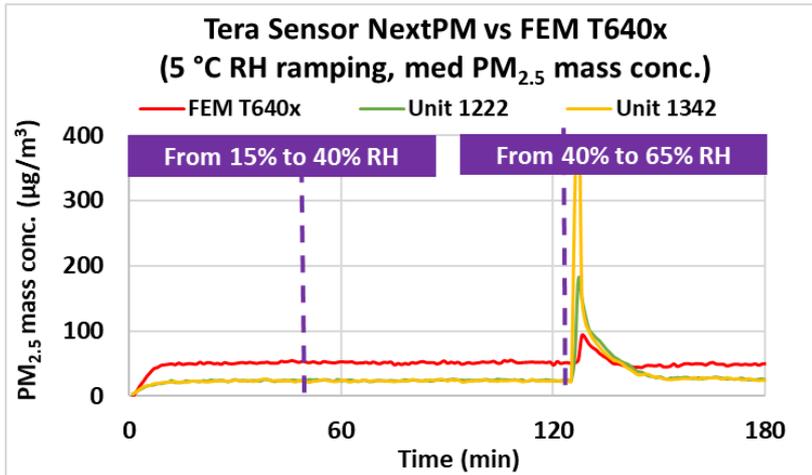
- Precision (effect of PM_{2.5} conc., temperature and relative humidity)



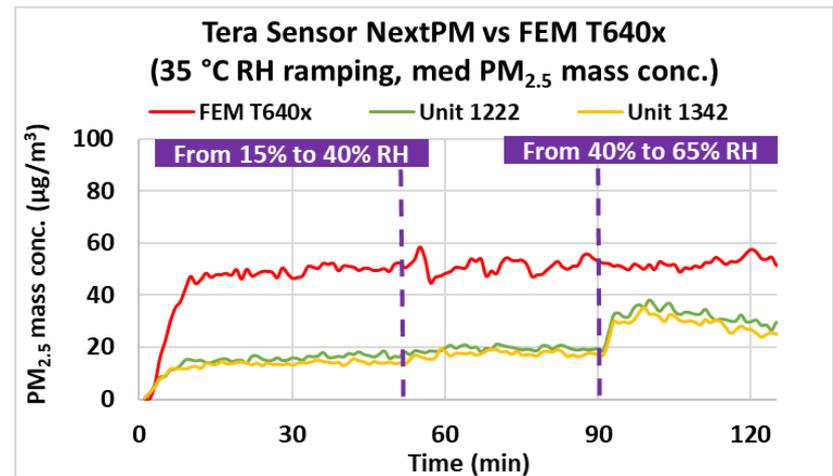
- Overall, the two NextPM sensors showed high precision for all combinations of PM_{2.5} conc., T, and RH.

Climate Susceptibility: NextPM (PM_{2.5})

Low Temp - RH ramping
(medium conc.)



High Temp – RH ramping
(medium conc.)



Discussion: PM_{2.5}

- **Accuracy:** The NextPM sensors underestimated PM_{2.5} concentration values compared to the FEM T640x PM_{2.5} mass concentration at 20 °C and 40% RH. The NextPM sensors showed fairly constant accuracy (34.2% to 39.2%) for all tested PM_{2.5} concentrations compared to the reference FEM T640x for the entirety of test.
- **Precision:** The two NextPM sensors exhibited high precision during all tested PM_{2.5} conc., T, and RH conditions.
- **Intra-model variability:** Low PM_{2.5} measurement variations were observed among the two NextPM sensors at 20 °C and 40% RH.
- **Data Recovery:** Data recovery for PM_{2.5} measurements was 100% for Units 1222 and 1342.
- **Bias:** N/A
- **Detection limit:** The detection limit cannot be estimated due to limitations in the chamber system design.
- **Response time:** Response time could not be studied due to the design of the chamber system. With a 1.6 m³ chamber volume, it was not possible to reach a high pollutant concentration within a short time.
- **Linear Correlation:** The two NextPM sensors showed very strong correlation/linear response with the corresponding FEM T640x PM_{2.5} measurement data ($R^2 > 0.99$).
- **Selectivity:** N/A for PM sensors test
- **Interferences:** N/A for PM sensors test
- **Note about PM_{1.0}:** The field evaluation compared the PM_{1.0} values reported from the NextPM sensors against the field GRIMM and T640 that reported PM_{1.0}. However, PM_{1.0} was not compared in this lab evaluation because at the time of lab testing (before March 2022) the lab T640x firmware upgrade to report PM_{1.0} was not finalized yet.

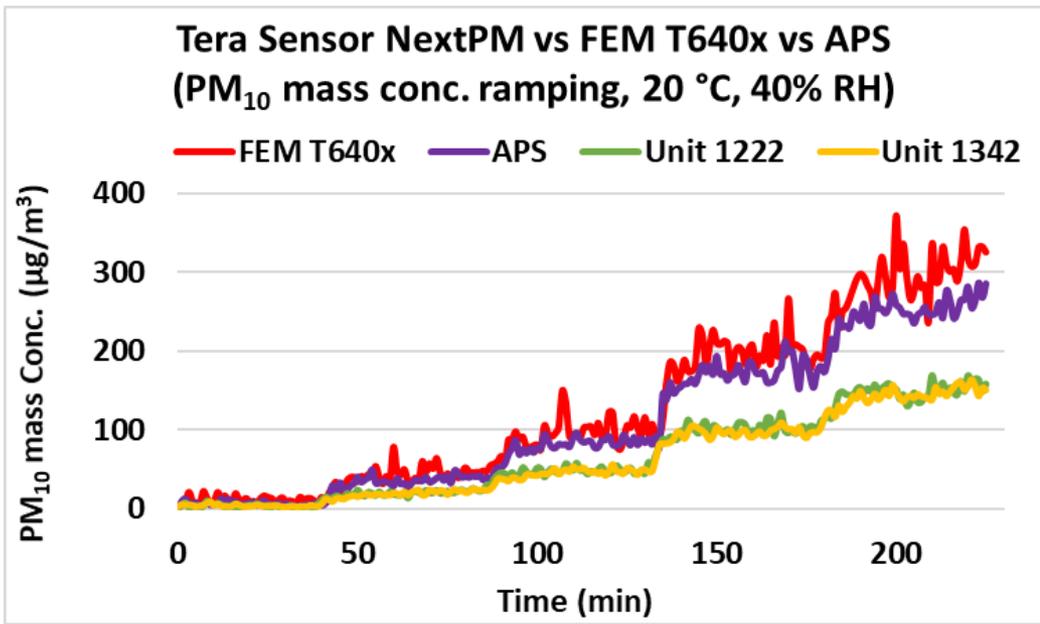
Discussion: PM_{2.5}

- **Measurement duration:** NextPM sensors report 10-sec averaged values.
- **Measurement frequency** NextPM sensors report 10-sec averaged values. The obtained data was condensed into 1-minute for calculation of statistics (e.g. data recovery, intra-model variability, mean, accuracy, precision), and to 5-minute averages for linear correlation studies against the FEM T640x.
- **Sensor contamination and expiration:** Prior to the laboratory evaluation, the NextPM sensors were tested in the field for two months. The PM_{2.5} laboratory studies lasted for about 9 days with intermittent non-operating periods and a storage period of ~ 3 months. For PM_{2.5} measurements, two of the three NextPM sensors maintained their functionalities and operated normally throughout the duration of the testing.
- **Concentration range:** Up to 1000 µg/m³ as suggested by the manufacturer. During the laboratory evaluation, the NextPM sensors were challenged with PM_{2.5} concentrations up to 300 µg/m³.
- **Drift:** N/A
- **Climate susceptibility:** During the lab studies, climate did not significantly impact precision. Spiked concentrations were observed at the RH change points, especially at the 65% RH change point. Increasing RH led to less underestimation compared to the FEM T640x.
- **Response to loss of power:** NextPM sensors were powered through the entirety of the lab tests.

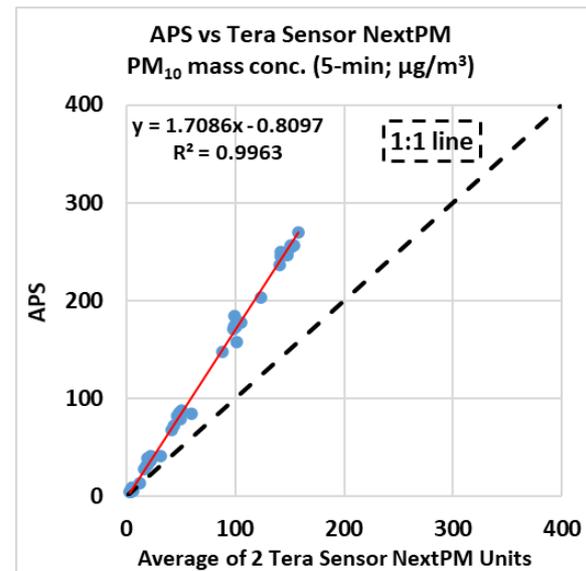
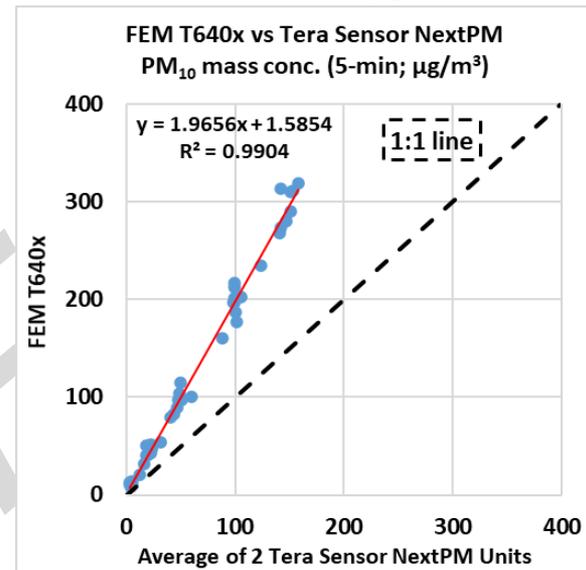
PM₁₀

1. **FEM T640x vs APS vs NextPM**
2. **Accuracy, data recovery, and intra-model variability**
3. **Climate susceptibility**
4. **Discussion**

NextPM vs FEM T640x vs APS (PM₁₀)



- The NextPM sensors tracked well with the PM₁₀ concentration variations as recorded by the FEM T640x and APS in the concentration range of 0 - 300 µg/m³.
- The NextPM sensors showed very strong correlations with both FEM T640x and APS PM₁₀ measurement data ($R^2 > 0.99$).



NextPM vs FEM T640x vs APS PM₁₀ Accuracy

- Accuracy (20 °C and 40% RH)

| Steady State # | Sensor Mean (µg/m ³) | FEM T640x (µg/m ³) | Accuracy (%) |
|----------------|----------------------------------|--------------------------------|--------------|
| 1 | 3.9 | 11.4 | 34.2 |
| 2 | 22.5 | 46.6 | 48.2 |
| 3 | 48.7 | 99.9 | 48.7 |
| 4 | 100.8 | 202.8 | 49.7 |
| 5 | 151.6 | 305.8 | 49.6 |

| Steady State # | Sensor Mean (µg/m ³) | APS (µg/m ³) | Accuracy (%) |
|----------------|----------------------------------|--------------------------|--------------|
| 1 | 3.9 | 5.5 | 71.3 |
| 2 | 22.5 | 38.7 | 58.1 |
| 3 | 48.7 | 85.0 | 57.3 |
| 4 | 100.8 | 177.6 | 56.8 |
| 5 | 151.6 | 259.2 | 58.5 |

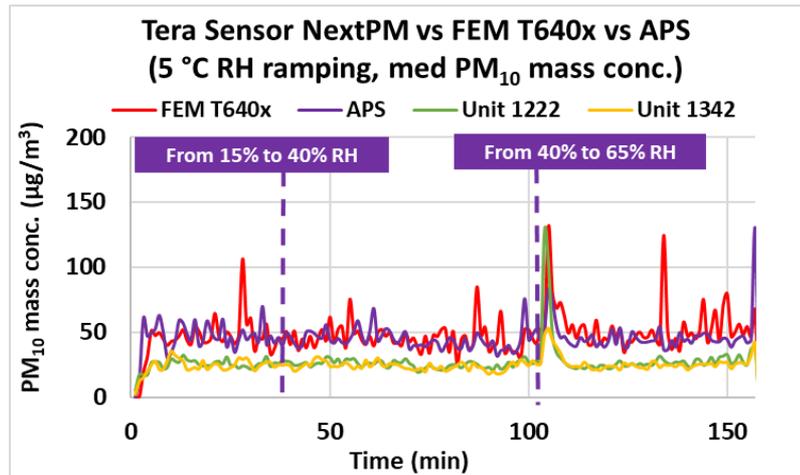
- The NextPM sensors underestimated PM₁₀ concentration values compared to the FEM T640x and APS PM₁₀ mass concentration at 20 °C and 40% RH. The NextPM sensors showed fairly constant accuracy (34.2% to 49.7% for the FEM T640x and 56.8% to 71.3% for the APS) for all tested PM₁₀ concentrations compared to the reference FEM T640x for the entirety of test.

NextPM Data Recovery and Intra-model Variability

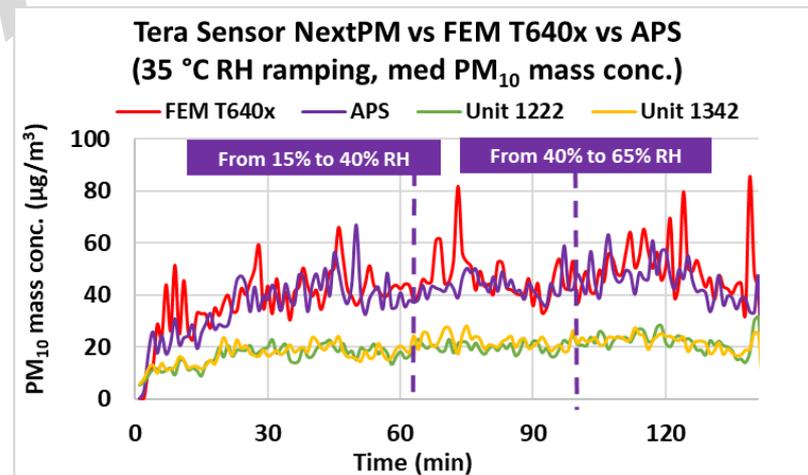
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Low Temp - RH ramping
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Discussion: PM₁₀

- **Accuracy:** The NextPM sensors underestimated PM₁₀ concentration values compared to the FEM T640x and APS PM₁₀ mass concentration at 20 °C and 40% RH. The NextPM sensors showed fairly constant accuracy (34.2% to 49.7% for the FEM T640x and 56.8% to 71.3% for the APS) for all tested PM₁₀ concentrations compared to the reference FEM T640x for the entirety of test.
- **Precision:** Due to the nature of Arizona Test Dust dispersion, the aerosol concentration showed some variability, therefore, the precision cannot be fairly estimated.
- **Intra-model variability:** Low PM₁₀ measurement variations were observed among the two NextPM sensors at 20 °C and 40% RH.
- **Data Recovery:** Data recovery for PM₁₀ measurements was 100% for Units 1222 and 1342.
- **Bias:** N/A
- **Detection limit:** The detection limit cannot be estimated due to limitations in the chamber system design.
- **Response time:** Response time could not be studied due to the design of the chamber system. With a 1.6 m³ chamber volume, it was not possible to reach a high pollutant concentration within a short time.
- **Linear Correlation:** The two NextPM sensors showed very strong correlation/linear response with the corresponding FEM T640x and APS PM₁₀ measurement data ($R^2 > 0.99$).
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- **Drift:** N/A
- **Climate susceptibility:** During the lab studies, climate did not significantly impact precision. Spiked concentrations were observed at the 65% RH change point.
- **Response to loss of power:** NextPM sensors were powered through the entirety of the lab tests.